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SILVER ZINC BATTERIES POWER SUPPLY FOR THE ATMOSPHERIC STRUCTURE SATELLITE EXPLORER XVII

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GODDARD SPACE FLIGHT CENTER

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SUMMARY

Silver zinc cells were utilized as the power supply for Explorer XVII because they offered the highest capacity per unit of weight of existing electrochemical couples. Tests to determine the feasibility of using these cells in a sealed sphere and under the expected power profile of the satellite were carried out at the Goddard Space Flight Center. The electric power system used on the satellite, cell characteristics, and associated outgassing data are presented.

Explorer XVII, the Atmospheric Structure Satellite, was launched on the second of April 1963. Its mission was to measure the density, composition, pressure and temperature of the earth's atmosphere. More than 780 commands were delivered by the power system, over a period of 100 days.

INTRODUCTION

The power supply for Explorer XVII was unique as compared to most satellites in that it was comprised of a primary battery system and was devoid of any solar power, conversion or regulating devices per se. Being a primary system without voltage regulation, dictated the use of dry-charged silver zinc cells. The need for retarding or controlling the outgassing of the cells in a sealed sphere and of an extended wet-stand life capability were recognized as being essential to the realization of achieving the projected orbital life of three months.

POWER SYSTEM

Solar cells were not used on Explorer XVII because of their unknown gas evolution characteristics. Therefore, the power supply consisted of a primary battery system as shown in figure 1. Sixty-seven dry-charged silver zinc cells ranging in capacity from 1 to 330 ampere hours were used. The energy output of the largest type cells approached 100 watt hours per pound and the average output was 65 watt hours per pound. The electric power requirements for the experiments, which were powered directly from the battery cells, was in excess of 110 watts. A simulated 90-day electrical load timing sequence program is given in Table 1. The complete battery system was successfully tested to this simulated program.

CELL TYPE SELECTION

Originally the power supply was based on the use of commercial primary type silver zinc cells; however, the wet-stand capability of these cells was limited to two to four months, which was considered too marginal for a projected orbital life of ninety days. Early in 1961, these cells were replaced with commercial secondary type cells which had a minimum wet-stand capability of six months. The secondary type cells were marginal in capacity as compared to the primary type and they were subsequently modified to give greater capacity. The cells finally selected for the Explorer XVII were modified Yardney HR type. These modified HR type cells were dry-charged, non-magnetic, and pre-loaded or de-peroxidized. The modified cells were superior to both the standard primary and secondary type cells in wet-stand life and in capacity as shown in figures 2 and 3.

CELL CHARACTERISTICS

Dry-charged cells were selected in lieu of wet or dry-unformed cells for various reasons. Dry storage is much less deliterious than wet storage. Dry-charged cells are much easier to place in service than unformed cells. If necessary, dry-charged cells may be used immediately after filling, whereas, unformed cells must be given formation cycles at relatively low rates. Unformed cells are not readily de-peroxidized and therefore would not give a single plateau output voltage. The single plateau output voltage was desirable on Explorer XVII because it allowed certain experiments to operate directly from the battery cells without the use of a voltage regulator or converter. Experiments which had self-contained voltage regulation also operated more efficiently. Figures 4 and 5 are typical discharge curves that show the voltage characteristic and the capacity difference between recharged cells and the initial discharge of a dry-charged cell.

Tests at Goddard on the modified HR type cells showed that they had ample capacity, a relatively flat voltage output and adequate wet-stand capability; however, it became evident that the outgassing of the dry-charged cells was much greater than on the recharged cells, as evidenced from figures 6 and 7.

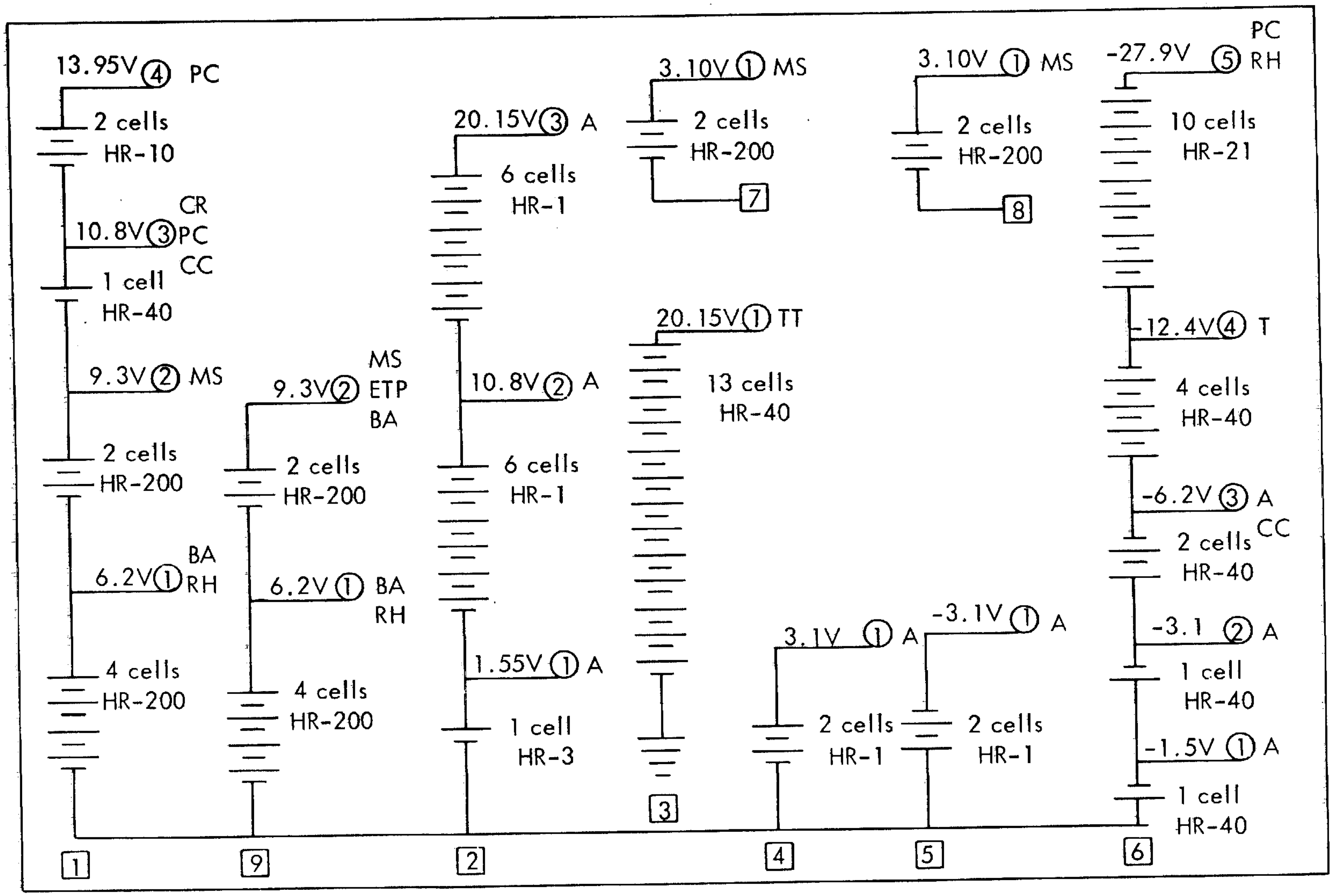
OUTGASSING

Chemical analysis of the outgassing products of dry-charged silver-zinc cells confirmed the hypothesis that it was essentially hydrogen. Based on this hypothesis, numerous tests were conducted on several materials which would react with hydrogen. Palladium monoxide, was finally selected as the most appropriate material. There was no attempt made to determine the amount of recombination, but only to the overall control of the pressure rise in a sealed chamber. Most of the tests were conducted over a ninety-day period in small pressure chambers with 1.3 to 1 free space volume ratio. The original concept called for sealed battery cans which approximated this ratio; however, it was later changed to allow the cells to vent directly into the satellite. The free space ratio in the satellite was approximately 11 to 1. Figures 8 and 9 are representative in showing the effect of the palladium monoxide in the control or retardation of the pressure rise. Figures 10 and 11 show that the pressure rise is directly proportional to the free space volume. Probably the most significant factor in the amount of increased pressure is the accelerated outgassing caused by the greater amount of chemical reaction within the cells at correspondingly higher temperatures. Figures 12 and 13 show the effect of temperature at 25 and 40 degrees centigrade. Results in most of the 90-day tests showed that as the capacity of the cell was consumed the rise in pressure leveled off and even declined slightly prior to complete discharge.

CONCLUSION

The use of primary silver zinc cells as the prime source of electrical energy for a scientific satellite has been clearly demonstrated by the success of Explorer XVII. Telemetered data showed no failure of the power supply during the 100 days prior to loss of reception due to the exhaustion of the cells in line 6 of figure 1. In view of the simplicity of the primary battery system and the success of Explorer XVII it is recommended that serious consideration be given to the further use of this type system in scientific satellites with an expected lifetime of less than six months.

BATTERY LAYOUT



1 - Line	PC - Program Card	CR - Command Receiver	ETP - Electron Temperature Probe
1 - TAp	BA - Bayard Alpert	CC - Command Counter	TT - Telemetry Transmitter
A - Aspect	RH - Red Head	MS - Mas Spectrometer	T - Tracking Transmitter

Figure 1

TEST PROCEDURE

Table 1
Electrical Load Timing Sequence – 90 Days

Time				Load Time			
Item	Days	Hours	Elapsed Days	On Minutes	Off	On Elapsed Hours	Command Number Per Item
1	1	24	1	5	15M	6.0	72
2	2	48	3	5	20M	15.6	116
3	2	48	5	0	48H	15.6	0
4	6	144	11	5	95M	22.8	87
5	14	336	25	5	11H – 55M	25.1	28
6	5	120	30	0	5D	25.1	0
7	1	24	31	5	15M	31.1	72
8	2	48	33	5	20M	40.7	116
9	2	48	35	0	48H	40.7	0
10	6	144	41	5	95M	47.9	87
11	14	336	55	5	11H – 55M	50.2	28
12	5	120	60	0	5D	50.2	0
13	1	24	61	5	15M	56.2	72
14	2	48	63	5	20M	65.8	116
15	2	48	65	0	48H	65.8	0
16	6	144	71	5	95M	73.0	87
17	14	336	85	5	11H – 55M	75.3	28
18	5	120	90	0	5D	75.3	0

M = minutes; H = hours; D = days
Total number of commands = 909
Time duration of each command = 5 minutes

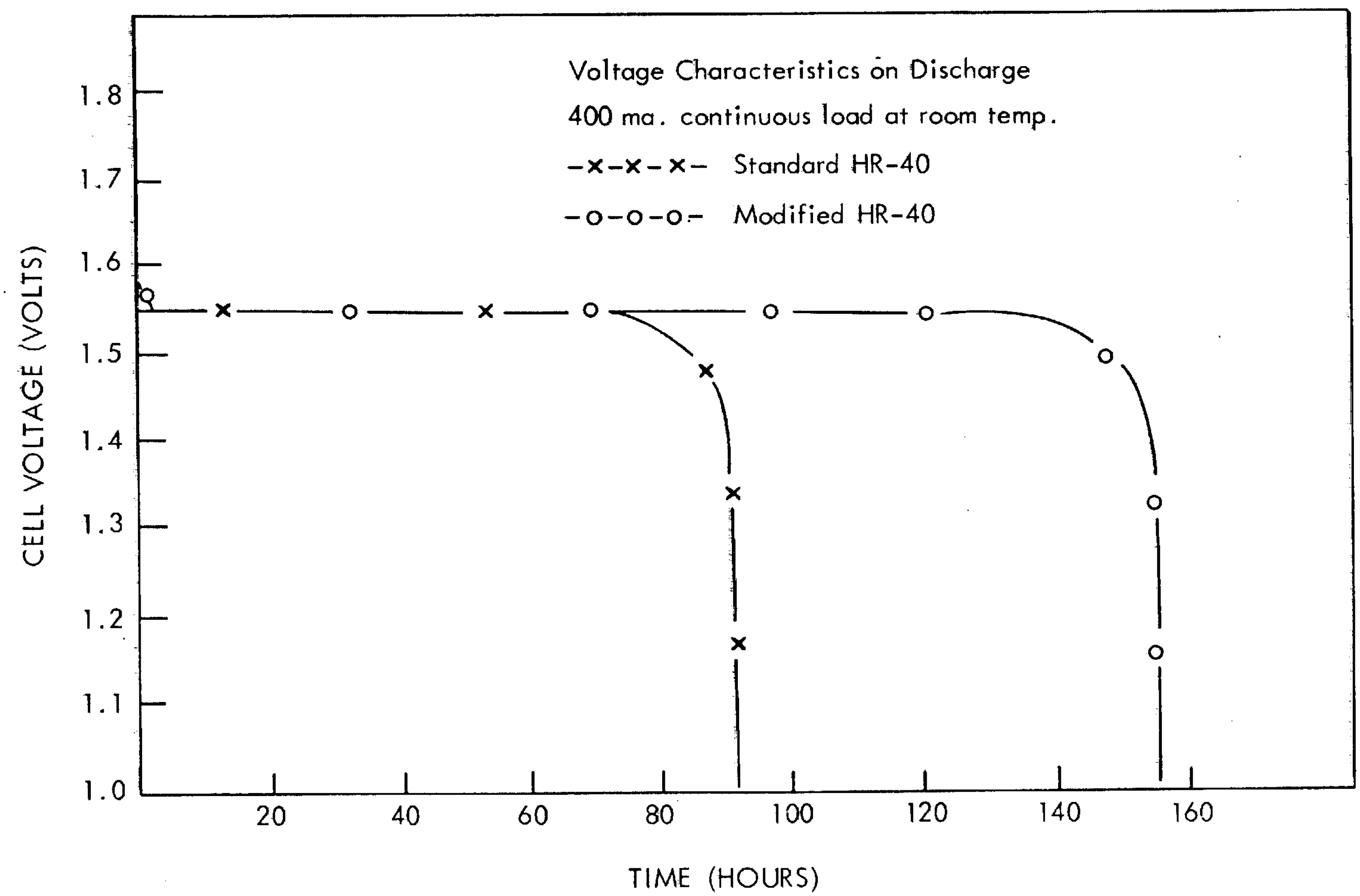
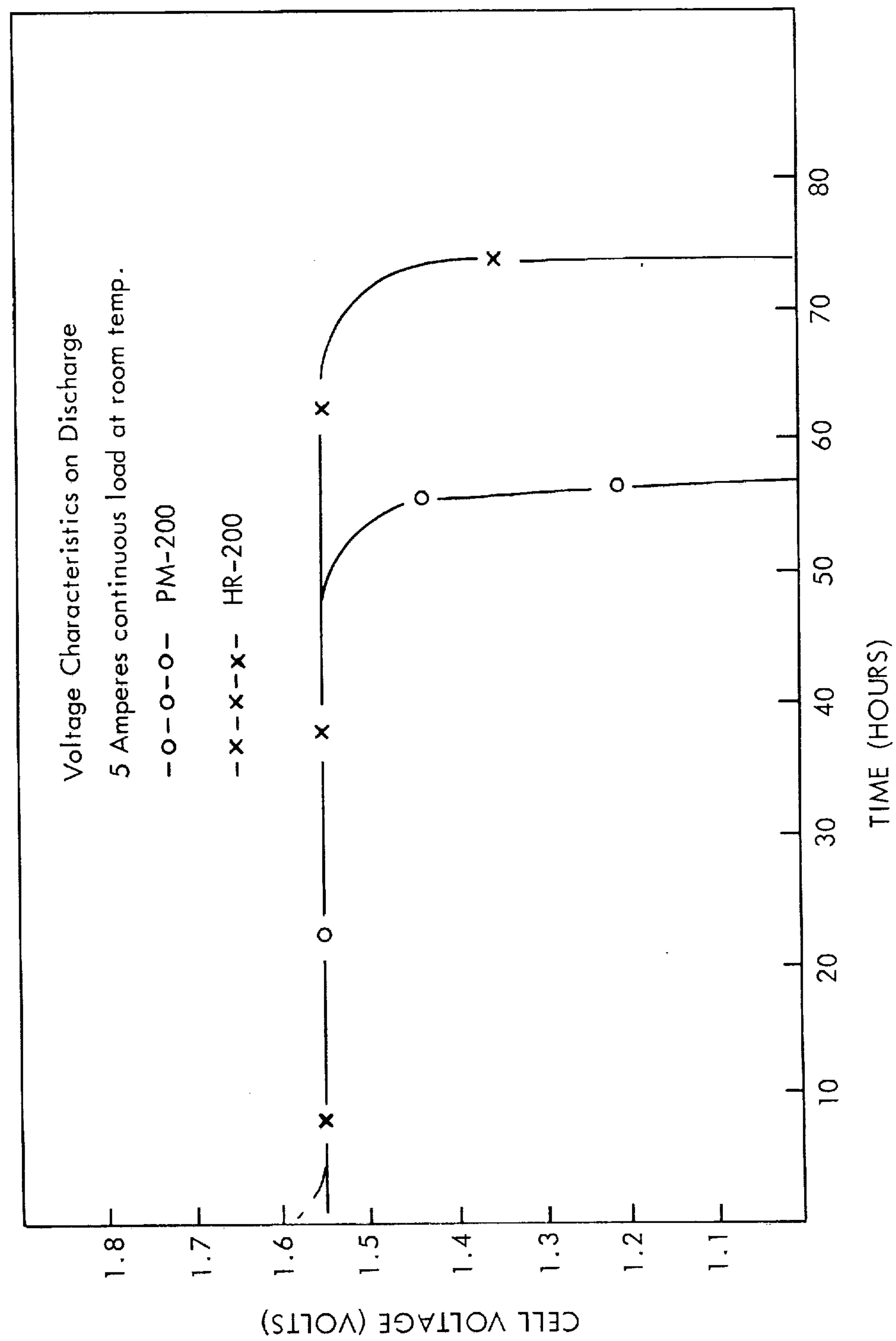
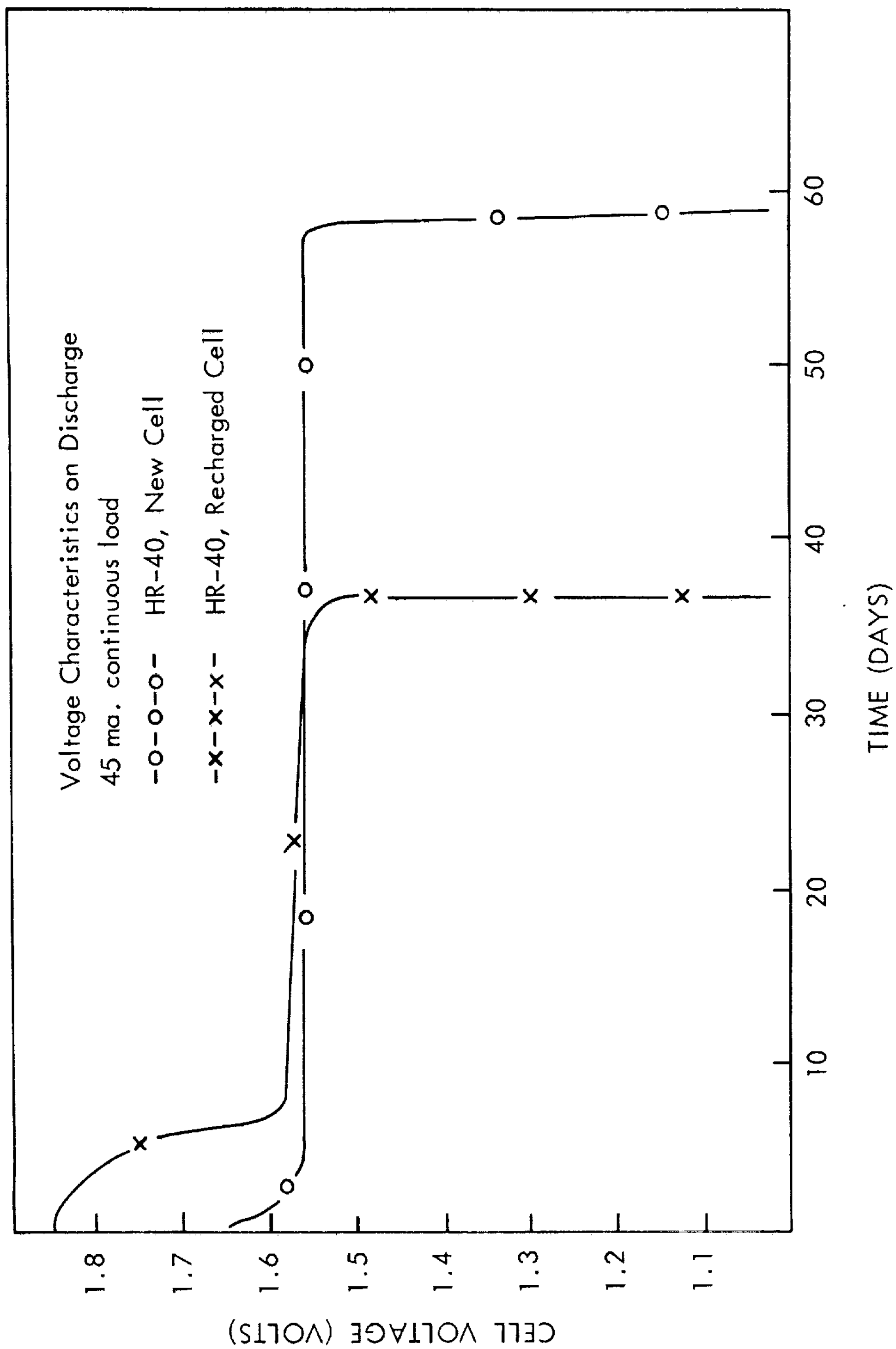

Voltage Characteristics on Discharge
400 ma. continuous load at room temp.
-x-x-x- Standard HR-40
-o-o-o- Modified HR-40
CELL VOLTAGE (VOLTS)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
20
40
60
80
100
120
140
160
TIME (HOURS)

Figure 2



Voltage Characteristics on Discharge
5 Amperes continuous load at room temp.
-o-o-o- PM-200
-x-x-x- HR-200
CELL VOLTAGE (VOLTS)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
10
20
30
40
50
60
70
80
TIME (HOURS)

Figure 3



Voltage Characteristics on Discharge
45 ma. continuous load
-o-o-o- HR-40, New Cell
-x-x-x- HR-40, Recharged Cell
CELL VOLTAGE (VOLTS)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
TIME (DAYS)
10
20
30
40
50
60

Figure 4

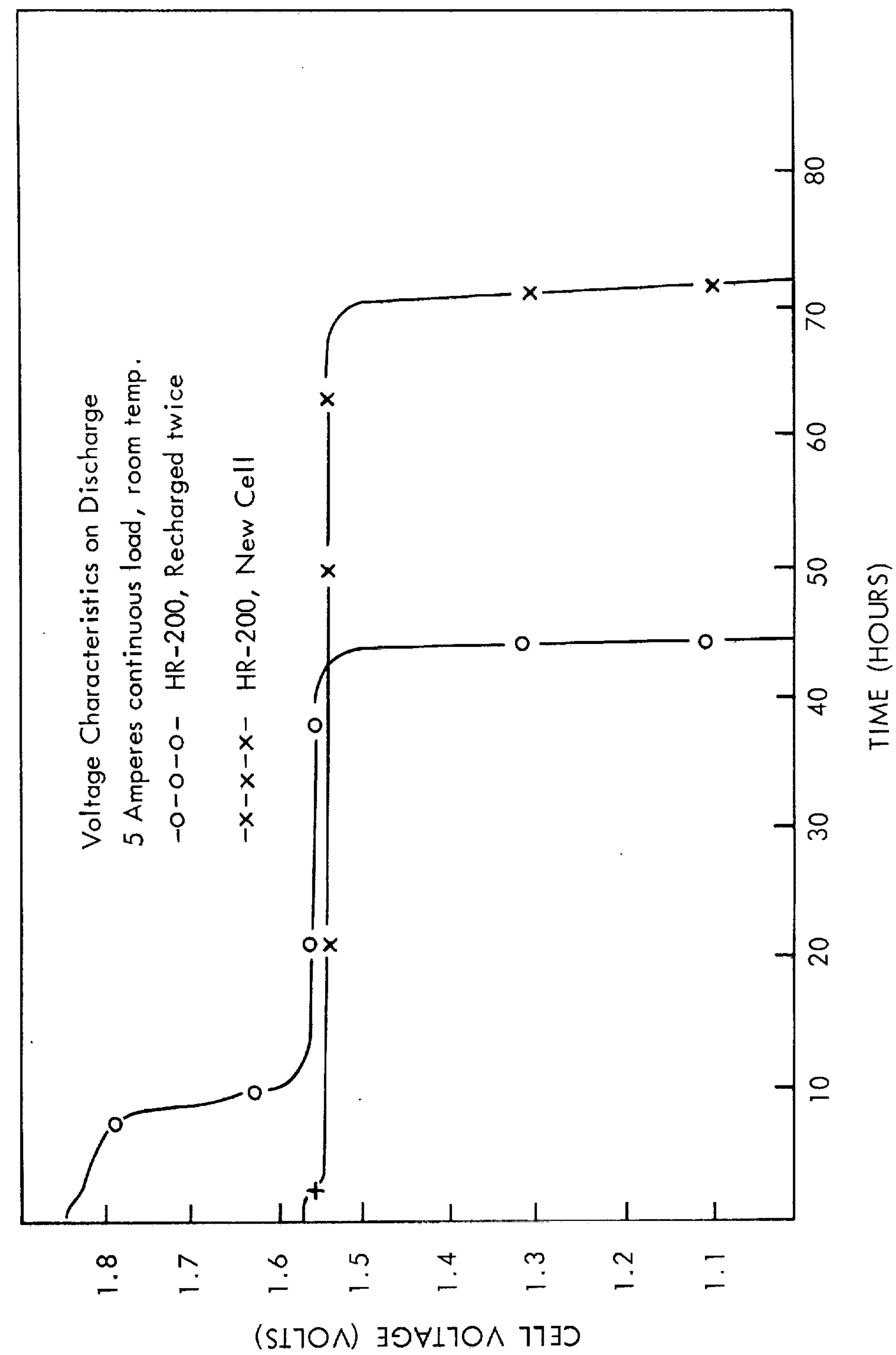
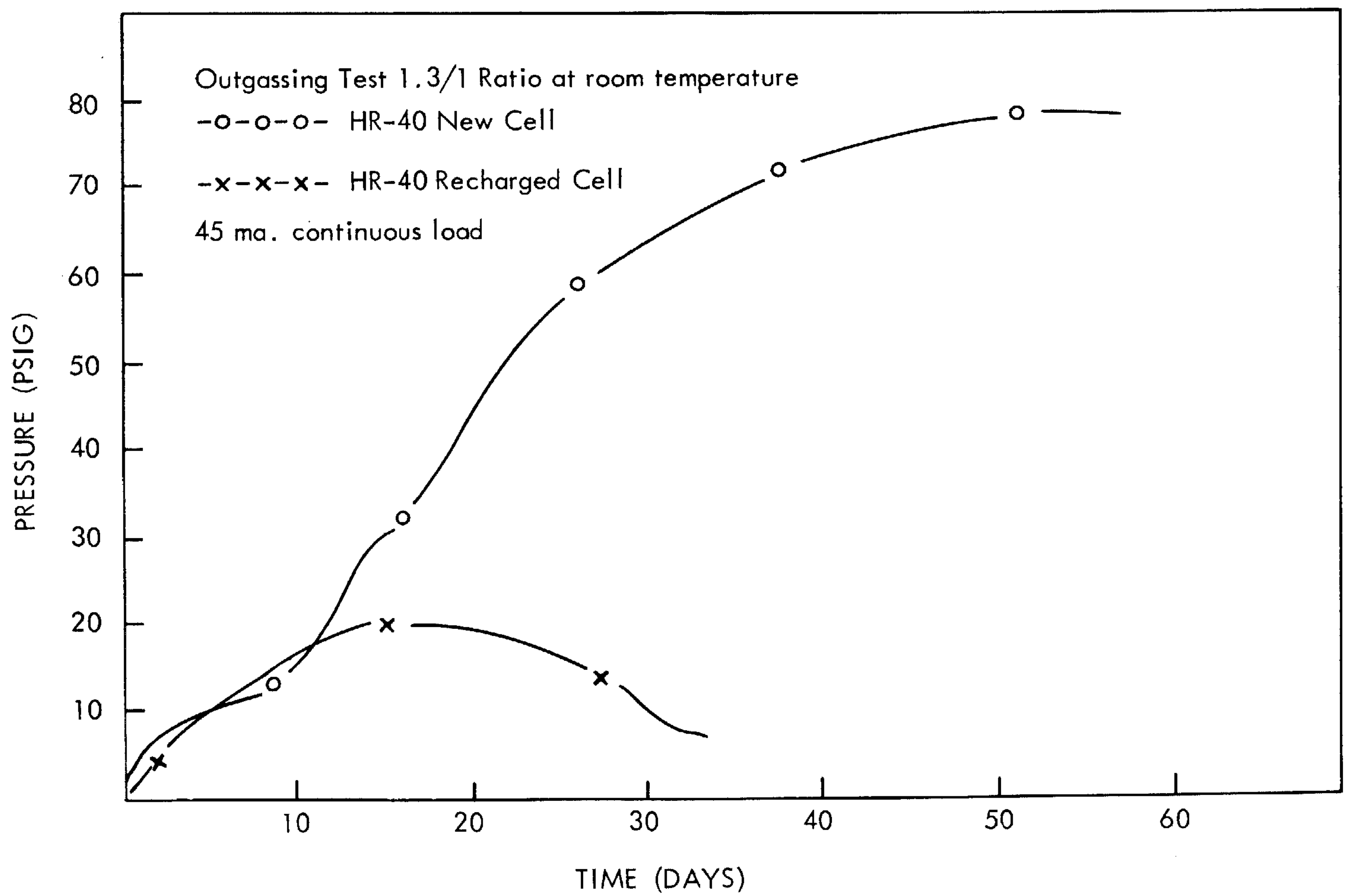

Voltage Characteristics on Discharge
5 Amperes continuous load, room temp.
-o-o-o- HR-200, Recharged twice
-x-x-x- HR-200, New Cell
CELL VOLTAGE (VOLTS)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
TIME (HOURS)
10
20
30
40
50
60
70
80

Figure 5



Outgassing Test 1.3/1 Ratio at room temperature
-o-o-o- HR-40 New Cell
-x-x-x- HR-40 Recharged Cell
45 ma. continuous load
PRESSURE (PSIG)
80
70
60
50
40
30
20
10
10
20
30
40
50
60
TIME (DAYS)

Figure 6

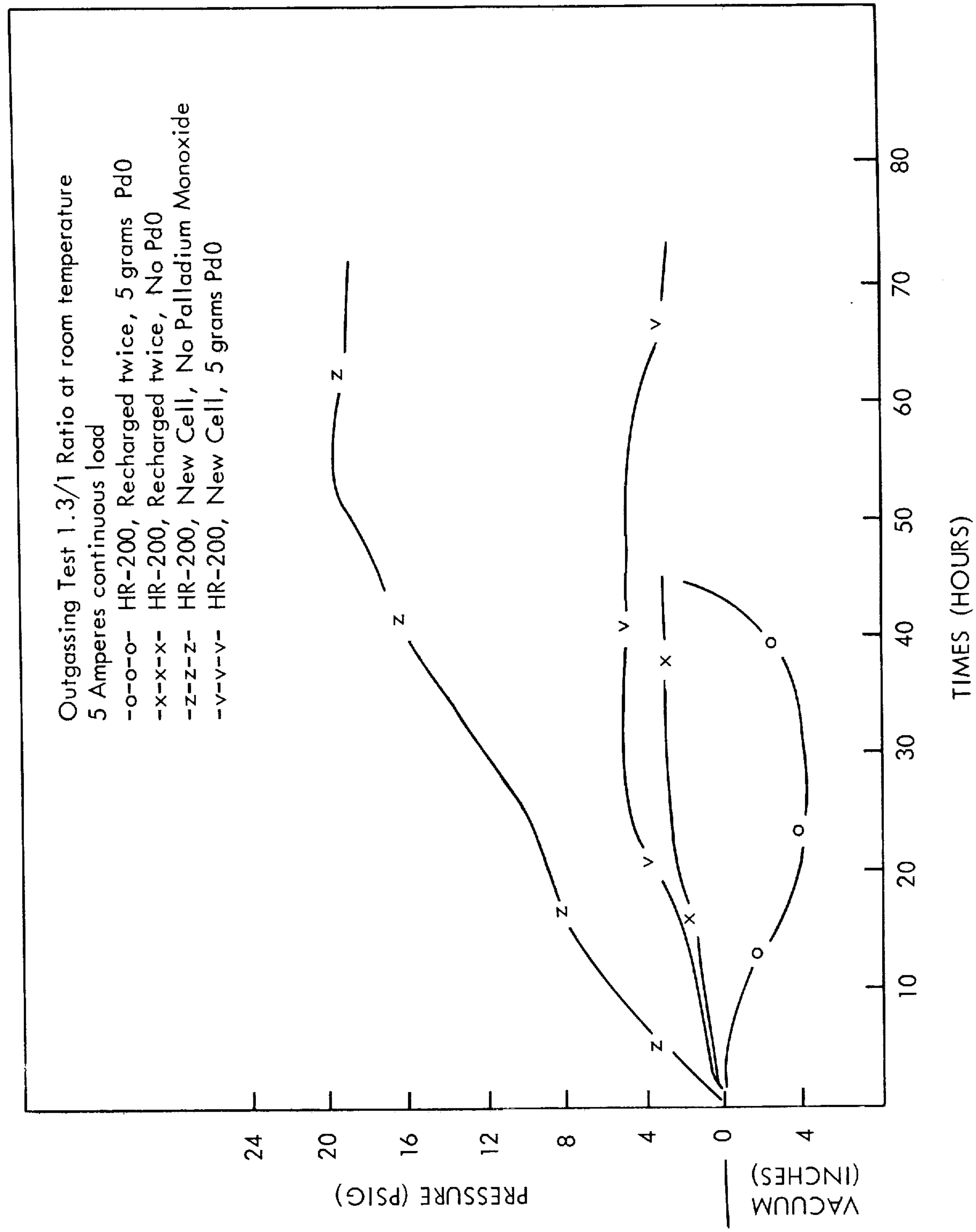
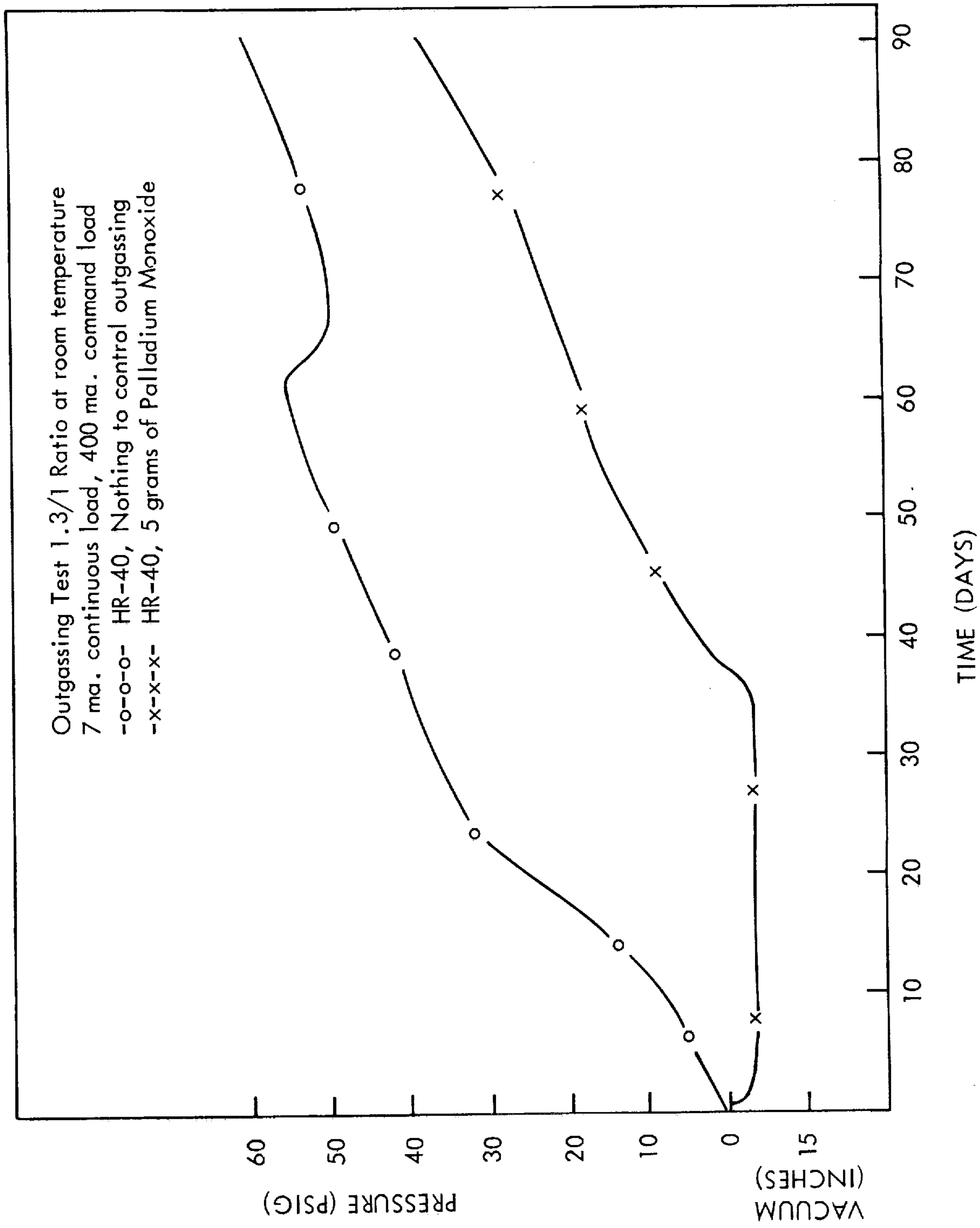
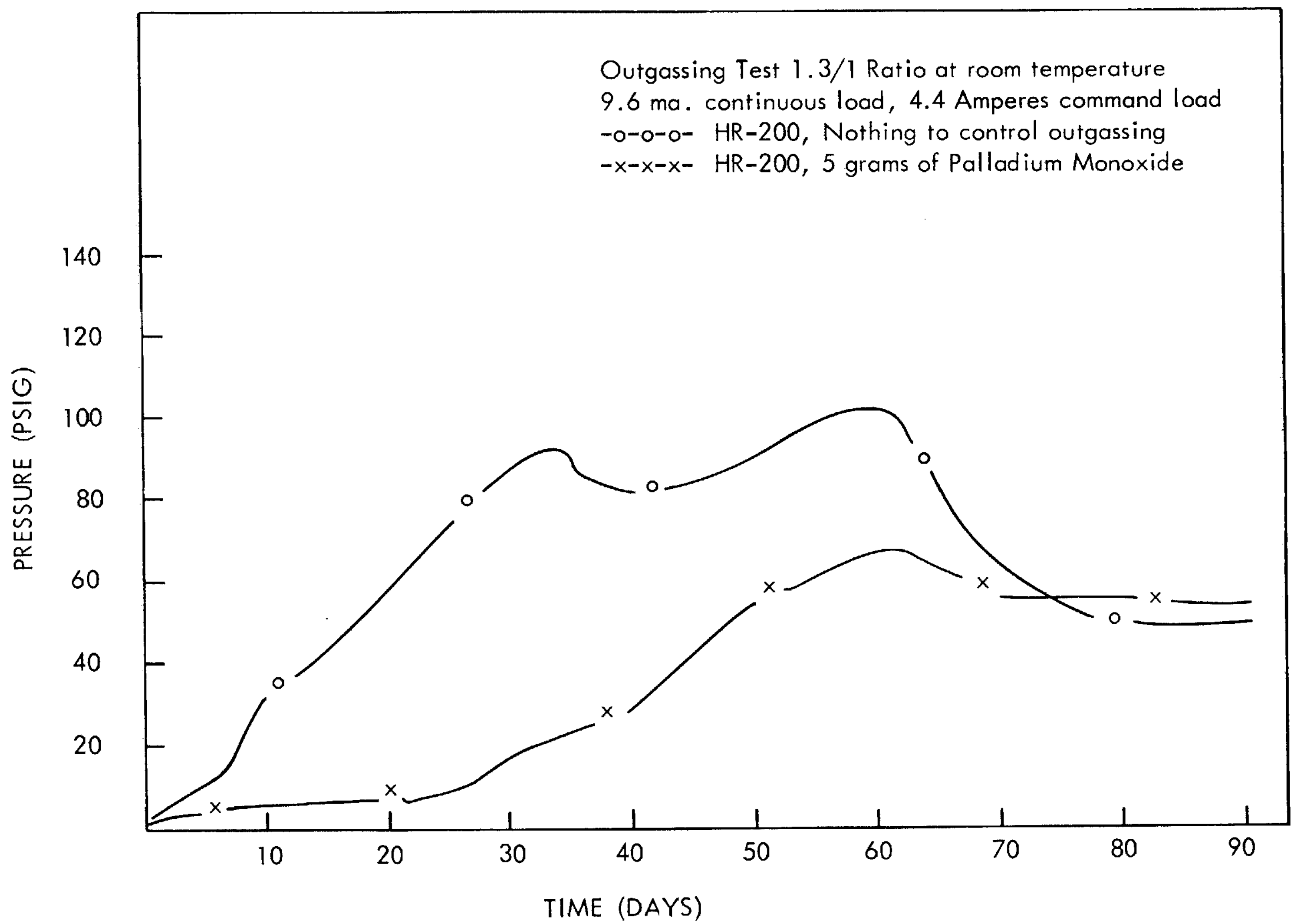

Outgassing Test 1.3/1 Ratio at room temperature
5 Amperes continuous load
-o-o-o- HR-200, Recharged twice, 5 grams PdO
-x-x-x- HR-200, Recharged twice, No PdO
-z-z-z- HR-200, New Cell, No Palladium Monoxide
-v-v-v- HR-200, New Cell, 5 grams PdO
PRESSURE (PSIG)
VACUUM (INCHES)
24
20
16
12
8
4
0
4
10
20
30
40
50
60
70
80
TIMES (HOURS)

Figure 7



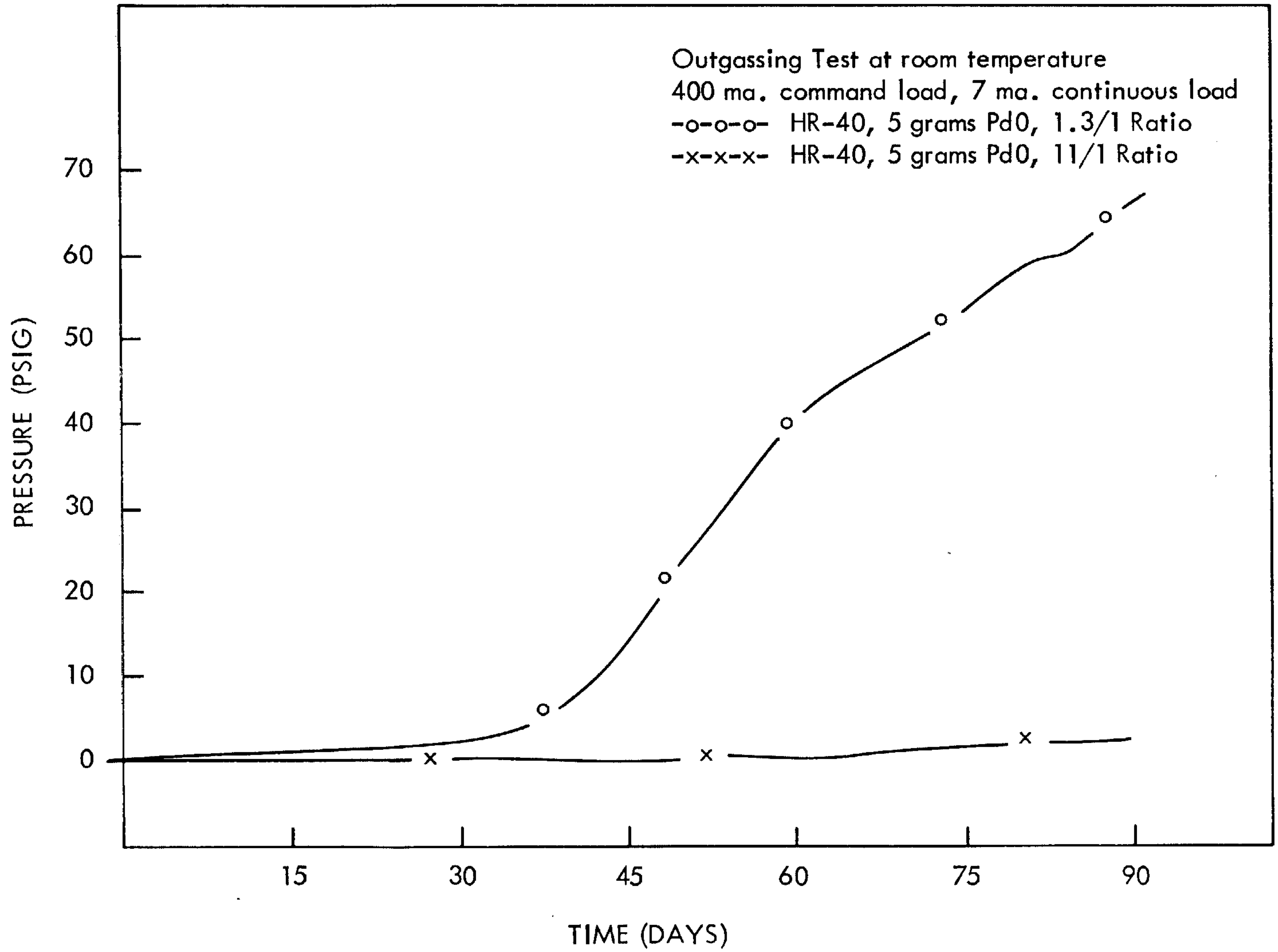
Outgassing Test 1.3/1 Ratio at room temperature
7 ma. continuous load, 400 ma. command load
-o-o-o- HR-40, Nothing to control outgassing
-x-x-x- HR-40, 5 grams of Palladium Monoxide
PRESSURE (PSIG)
VACUUM (INCHES)
60
50
40
30
20
10
0
15
10
20
30
40
50
60
70
80
90
TIME (DAYS)

Figure 8



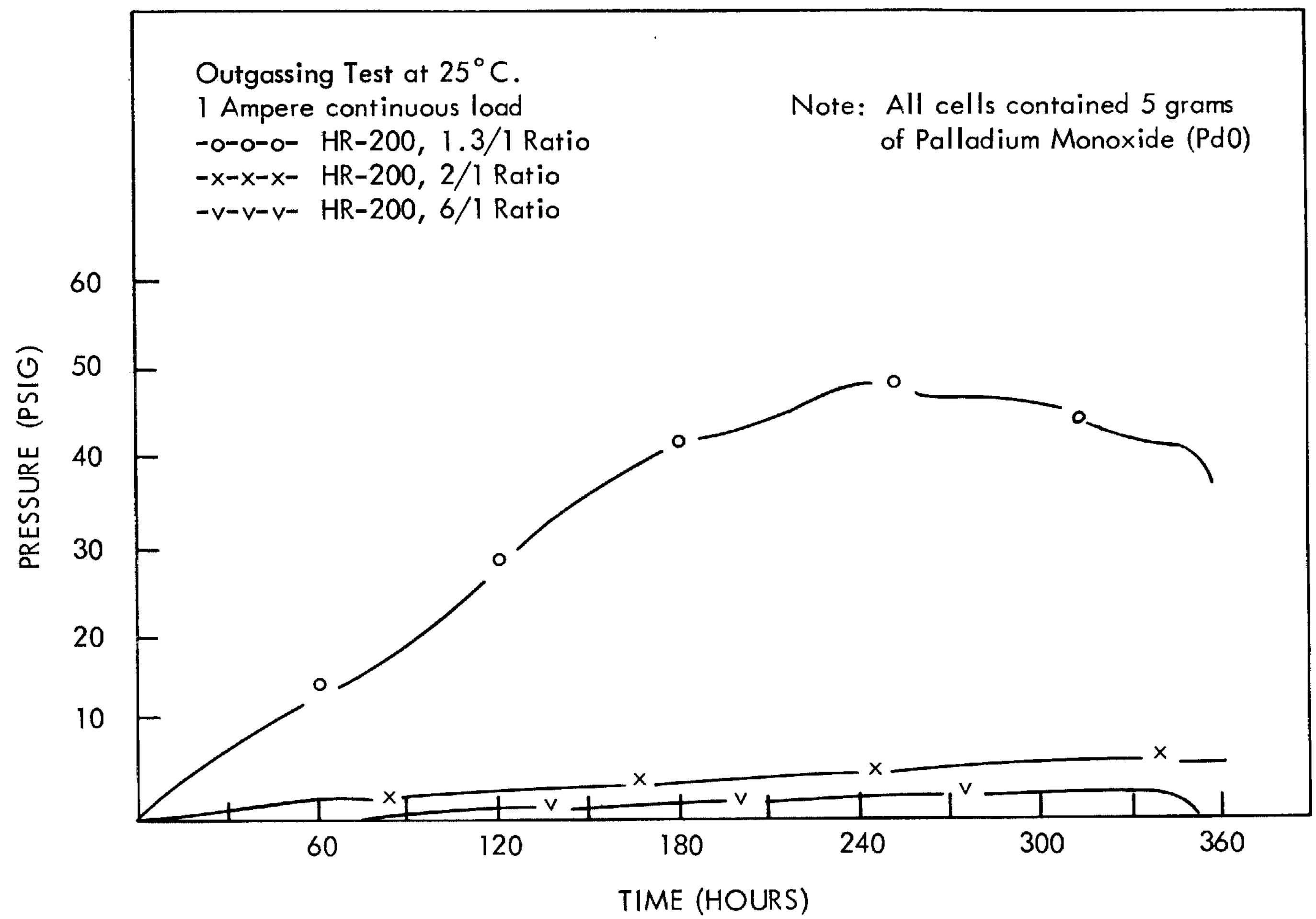
Outgassing Test 1.3/1 Ratio at room temperature
9.6 ma. continuous load, 4.4 Amperes command load
-o-o-o- HR-200, Nothing to control outgassing
-x-x-x- HR-200, 5 grams of Palladium Monoxide
140
120
100
80
60
40
20
PRESSURE (PSIG)
10
20
30
40
50
60
70
80
90
TIME (DAYS)

Figure 9



Outgassing Test at room temperature
400 ma. command load, 7 ma. continuous load
-o-o-o- HR-40, 5 grams PdO, 1.3/1 Ratio
-x-x-x- HR-40, 5 grams PdO, 11/1 Ratio
PRESSURE (PSIG)
70
60
50
40
30
20
10
0
15
30
45
60
75
90
TIME (DAYS)

Figure 10



Outgassing Test at 25° C.
1 Ampere continuous load
-o-o-o- HR-200, 1.3/1 Ratio
-x-x-x- HR-200, 2/1 Ratio
-v-v-v- HR-200, 6/1 Ratio
Note: All cells contained 5 grams of Palladium Monoxide (Pd0)
PRESSURE (PSIG)
60
50
40
30
20
10
60
120
180
240
300
360
TIME (HOURS)

Figure 11

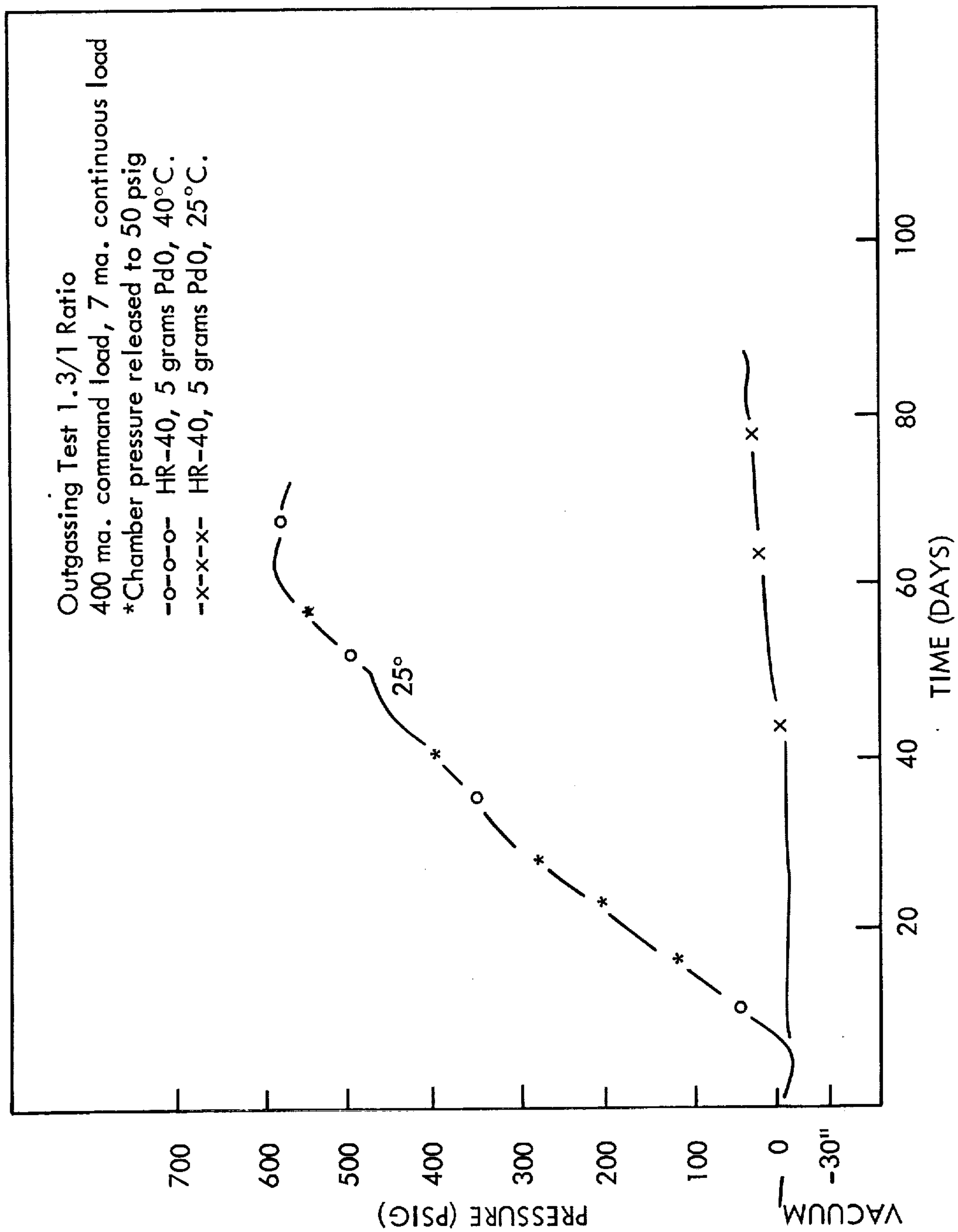

Outgassing Test 1.3/1 Ratio
400 ma. command load, 7 ma. continuous load
*Chamber pressure released to 50 psig
-o-o-o- HR-40, 5 grams PdO, 40°C.
-x-x-x- HR-40, 5 grams PdO, 25°C.
25°
PRESSURE (PSIG)
VACUUM
700
600
500
400
300
200
100
0
-30"
20
40
60
80
100
TIME (DAYS)

Figure 12

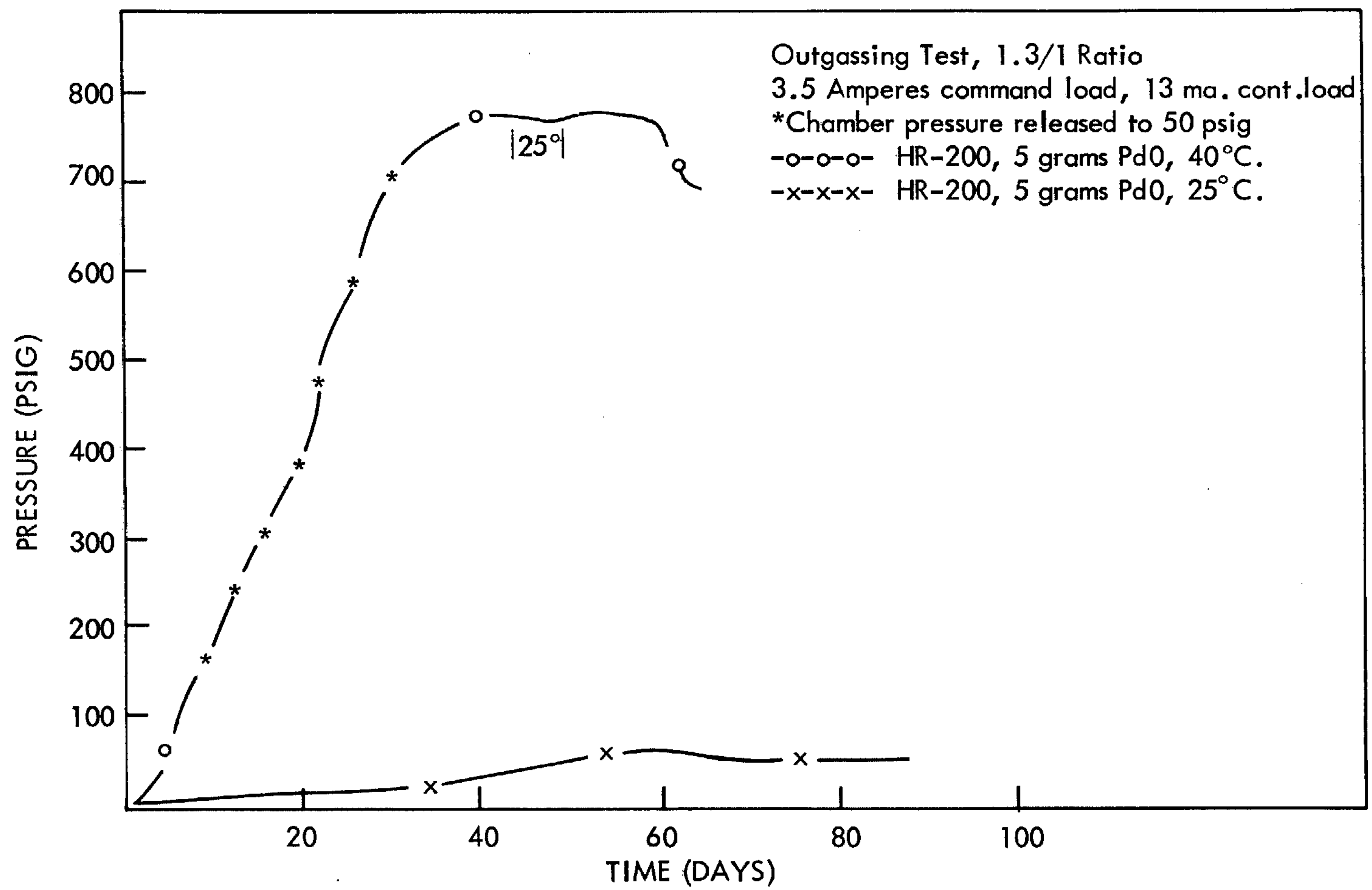

Outgassing Test, 1.3/1 Ratio
3.5 Amperes command load, 13 ma. cont.load
*Chamber pressure released to 50 psig
-o-o-o- HR-200, 5 grams Pd0, 40°C.
-x-x-x- HR-200, 5 grams Pd0, 25°C.
|25°|
800
700
600
500
400
300
200
100
PRESSURE (PSIG)
20
40
60
80
100
TIME (DAYS)

Figure 13